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Explicit and implicit anosognosia or upper limb motor impairment

Gianna Cocchini[a,]
Nicoletta Beschin[a, b]
Aikaterini Fotopoulou[c]
Sergio Della Sala[d]

[a] Psychology Department, Goldsmiths University of London, New Cross, London, SW14 6NW, UK

[b] Rehabilitation Department, Gallarate Hospital, Italy

[c] Institute of Psychiatry, King's College, University of London, UK

[d] Human Cognitive Neuroscience, and Centre for Cognitive Ageing and Cognitive Epidemiology, Psychology, University of Edinburgh, UK

Abstract If asked directly, anosognosic patients deny or seriously underestimate their motor difficulties. However explicit denial of hemiplegia does not necessarily imply a lack of insight of the deficit. In this study we explored explicit and implicit awareness for upper limb motor impairment in a group of 30 right-brain damaged patients. Explicit awareness was assessed using a questionnaire (the VATAm) in which patients are asked to rate their motor abilities, whereas implicit awareness was assessed by means of a newly developed test (BMT – bimanual task). This test requires the performance of a series of bimanual tasks that can be better performed using two hands, but could also be performed using one hand only. With the BMT, patients' performance rather than their verbal reports is evaluated and scored as an index of awareness. Paretic patients with anosognosia tend to approach these tasks as if they could use both hands. Our findings showed that explicit and implicit awareness for motor deficits can be dissociated, and they may be differently affected by feedback suggesting that different underlying mechanisms may account for the multi-factorial phenomenon of anosognosia.

Keywords Anosognosia; Unawareness; Hemiplegia; Brain damage

1. Introduction

There is growing agreement amongst researchers to consider anosognosia as a multi-factorial phenomenon (Cocchini et al., 2009, Cocchini et al., 2002, Davies et al., 2005, Marcel et al., 2004, McGlynn and Schacter, 1989, Orfei et al., 2007, Vallar and Ronchi, 2006 and Vuilleumier, 2004; see also Prigatano, 2010). This suggests that different mechanisms may be responsible for lack of awareness, and that different aspects of anosognosia should be considered (Heilman et al., 1998 and Marcel et al., 2004). Despite this possible heterogeneous scenario, most of the researchers' attention has been directed to systematically investigating explicit forms of unawareness, mainly relying on meta-cognition tasks. In this context patients are typically asked to respond to more or less direct questions about their deficit (e.g. Berti, Làdavas, & Della Corte, 1996), rate their ability in performing motor tasks (e.g. Della Sala, Cocchini, Beschin, & Cameron, 2009) or estimate their performance before and after having performed specific tasks (e.g. Marcel et al., 2004).

More subtle aspects of anosognosia, which also may provide relevant information about the nature of patients' unawareness, have received only qualified attention. Implicit processing of the information about one's own condition is one such neglected aspect. Considering patients' incidental comments or their behaviour in specific situations may reveal their actual beliefs (insight) about their conditions. For example, Ramachandran and Blakeslee (1998) anecdotally described a patient oblivious of his severe paresis who nevertheless commented, "I can't wait to go back to two-fisted beer drinking" (Ramachandran & Blakeslee, 1998, p. 143). Similarly Berti, Làdavas, Stracciari, Giannarelli, and Ossola (1998) described a hemiplegic patient who denied any motor impairment but whose "tacit knowledge of her physical condition was apparent in most conversations" (p. 21). Marcel et al. (2004) compared patients' ratings of their own motor abilities with their own ratings in judging how well the examiner would perform the same tasks had he been in the patient's current situation. The authors observed that up to 50% of right-brain damaged patients rated the examiner's ability consistently lower than their own. Nardone, Ward, Fotopoulou, and Turnbull (2007) described 2 anosognosic patients who showed an increment of simple reaction times when a word related to movement was presented with the target. These findings suggest that even patients who firmly deny any motor problem may have access to some type of implicit knowledge about their motor impairment.

A possible dissociation between implicit and explicit knowledge, or "dissociation of knowledge" (Bisiach & Geminiani, 1991), has strong theoretical implications about the nature of anosognosia. Information about implicit awareness is fundamental to provide relevant support to theoretical approaches; indeed some of these imply some insight into the deficit. For example, the motivational theory suggests that anosognosia is a psychological defence mechanism (Turnbull and Solms, 2007a, Turnbull and Solms, 2007b, Weinstein and Kahn, 1955 and Weinstein, 1991); however in order to "trigger" the denial process the patient must have processed some information about the deficit and have some "knowledge" of the deficit. On the contrary, other theories postulate that anosognosic patients lack the necessary information about their motor deficit, or the feedback information is incorrectly interpreted, resulting in lack of explicit and implicit awareness of the deficit. For example, the feed-forward theory by Gold, Adair, Jacobs, and Heilman (1994; see Fotopoulou et al., 2008 for a revised interpretation) identifies in the intention to move the "defective" stage that leads to lack of awareness. According to this interpretation, anosognosics' intentional systems do not formulate expectations about movements and the information about the feedback is correctly processed (i.e. no movement occurred); however since there is no mismatch between intention to move and feedback, the lack of movement is not interpreted as a failure. Other such theories suggest that anosognosia is linked to a malfunction in monitoring the impairment (Jenkinson et al., 2009 and Rubens and Garrett, 1991) or of the self-evaluation process (Levine, 1990). According to these theories, a lack of explicit knowledge of the motor impairment would be likely associated with lack of insight. Therefore, considering that anosognosia seems to be a multi-factorial phenomenon, different patients' unawareness may underline different causes and further knowledge about patients' implicit knowledge about the motor impairment would contribute to a better understanding of the nature of each patient's anosognosia and guide theoretical interpretation.

Clearly patients' knowledge of the deficit, at an explicit or implicit level, depends on the individual ability to perceive and process information from the surrounding environment and from the internal status of the body (Craig, 2010). Some authors have observed how simple exposure to a failure may considerably increase some patients' explicit awareness. We could call this phenomenon "empirical learning". Berti et al. (1996; see also Marcel et al., 2004) reported that some patients, but not all, tend to update the evaluation of their own motor ability after having performed bimanual or bipedal motor tasks. However, these authors, as many others, have described patients who vigorously denied any motor impairment despite clear evidence to the contrary (see Prigatano, 2010). Yet, some patients may still deny their deficit but react to the examiner's request to move the paretic limb in quite a defensive way (e.g. "You are beginning to ask me too many things!" Berti et al., 1998, p. 29). This suggests that anosognosia cannot be invariably accounted for as due to monitoring deficits or incorrect self-evaluation or lack of motor intention. Indeed, it seems that some patients have some knowledge of their deficit but that this information fails to reach more explicit levels of awareness. More systematic investigations about the effect of empirical learning on explicit and implicit forms of awareness could provide additional understanding of the nature of anosognosia.

The aim of the present study is to identify different levels of awareness and investigate possible factors that may prevent patients from becoming fully aware of their motor impairment.

2. Materials and Methods

2.1. Participants

2.1.1. Brain damaged patients

A group of 30 (11 females and 19 males) stroke patients with unilateral right hemisphere damage were recruited for the present study. Demographic and clinical data are reported in Table 1.

To be considered for the experiment, patients had to present with clear left upper limb motor impairment, which was assessed by means of the Motricity Index (Wade, 1992). During this assessment, the patients sat in a chair or a wheelchair. Three left upper limb movements were assessed: "pinch grip", "elbow flexion" and "shoulder abduction". Following published instructions (Wade, 1992), for each of these movements, a score from 0 (no movement) to 33 (normal power) was given. The score for upper limb movement was then calculated by adding the score for the three movements *plus* 1, to give a total score between 1 (severe motor impairment) and 100 (no motor impairment). Poor performance due to apraxia, tremor or ataxia was not considered as evidence of paresis. Details are reported in Table 1.

On a background cognitive assessment, extrapersonal neglect was assessed by means of Line (Albert, 1973) and Star (Wilson, Cockburn, & Halligan, 1987) Cancellation Tests, and by means of a Line Bisection Test (Wilson et al., 1987). Eighteen (60%) patients (of whom 12 of 17 patients had lesions to the frontal and parietal lobes) showed some evidence of left extrapersonal neglect on at least one test. Personal neglect was assessed by means of the Fluff Test (Cocchini, Beschin, & Jehkonen, 2001), the Comb/Razor Test (Beschin & Robertson, 1997) and the One Item Test (Bisiach, Perani, Vallar, & Berti, 1986). Nineteen (63%) patients (of whom 11 of 17 patients had lesions to the fronto-parietal areas) showed some evidence of left personal neglect on at least one test. Reasoning abilities were assessed by means of the Cognitive Estimates Test (Della Sala, MacPherson, Philips, Sacco, & Spinnler, 2003) Only 2 (7%) patients (both with brain lesions limited to the frontal and parietal areas) showed impairment on this test. Finally, data related to short- and long-term verbal memory abilities were collected for 20 patients by means of Digit span and Prose Memory (Spinnler & Tognoni, 1987). One patient (5%) showed short-term and 4 (20%) long-term memory impairment (all but 1 with brain lesions limited to the frontal and parietal areas).

2.2. Control participants

Two groups of volunteers acted as controls. One group (healthy controls) consisted of 19 right-handed healthy participants. See Table 1 for demographic data.

The other group (control patients) consisted of 7 patients with motor disorders of their upper limb (i.e. Motor Index score lower than 85/100) not due to neurological causes (e.g. bone fractures). Five of them had a motor impairment of their left upper limb, and 2 had a motor impairment of their right upper limb. See Table 1 for demographic and clinical data.

Age did not differ significantly (i.e. $F > 1$) across the three groups of participants. A significant effect of years of formal education was found ($F(2,55) = 8.66$; $p < .001$) and Games-Howell post hoc analyses showed that control patients had on average more formal years of education than healthy volunteers and brain damaged patients (both with $p < .001$). The motor impairment of the control patient group was significantly less severe than that of the brain damaged patients ($F(1,36) = 24.17$; $p < .001$). According to some authors (e.g. Levine, 1990) a mild motor deficit is more likely to be associated to unawareness. Therefore, had this difference affected patients' awareness in our study, we should have observed a stronger negative effect on control patients than on brain damaged patients.

All participants gave informed consent prior to taking part in the study.

2.3. Method and procedure

2.3.1. Explicit anosognosia

2.3.1.1. The VATAm

To assess evidence of explicit anosognosia for upper limb motor deficits, all brain damaged patients and control patients underwent the VATAm (Della Sala et al., 2009). In this test, patients are requested to rate (from 0 = no problem to 3 = severe problem), one at a time, their ability to perform a series of simple everyday motor tasks, such as clapping their hands. For the purpose of this study only the 8 bimanual tasks were considered (score range 0–24). There were also 4 check questions, for which the expected ratings lay at one or another extreme of the scale. Performance on the check questions was not considered in the actual score, as these questions were used only to ensure the participants' compliance and reliability. The participants' self-evaluation was compared with the ratings of their caregivers (not part of the control groups) who filled in the questionnaire evaluating the patient's motor skills. The resulting score, i.e. the caregiver–patient discrepancy value, obtained by subtracting the patient's self-rating of the 8 bimanual tasks from those of their caregivers, could be checked against available norms (Della Sala et al., 2009). This score indicates the patient's degree of awareness/unawareness for their upper motor impairment. In the VATAm, the possible discrepancy value for the bimanual actions of the upper limb ranges from −24 (negative values generally indicate patient overestimation of the motor deficit compared to the caregiver's judgment) to +24 (positive values generally indicate patient underestimation of the motor deficit compared to the caregiver's judgment, i.e. unawareness of their own deficits). Following the norms set in Della Sala et al. (2009), values falling between 3.8 and 8.0, 8.1 and 16.0 or 16.1 and 24.0 were taken to indicate mild, moderate or severe anosognosia, respectively.

2.3.2. Implicit anosognosia

2.3.2.1. Experimental bimanual task (BMT)

Implicit anosognosia for upper limb motor disorder was assessed by means of the BMT. Participants were asked to perform 8 simple everyday tasks (selected after a series of pilot studies) using real objects (see Table 2 for a list of the tasks). All these tasks are usually better performed using both hands (e.g. holding a two-handle tray with two hands, one at each extremity – see Fig. 1a) but could also be performed using only one hand approaching the task in different way ("aware strategy" – e.g. holding the two-handle tray by placing one hand underneath the centre of the tray – see Fig. 1b). However, in order to adopt the "aware strategy", patients had to have some knowledge of their motor impairment. Indeed, if they were unaware of their motor difficulties, they would not adopt the correct strategy and behave as if they could use both hands ("Anosognosia" – e.g. placing the unimpaired hand at one extremity – see Fig. 1c), hence failing to perform the task. See Table 2 for details about each task strategy and evidence of failure.

The examiner placed the objects one at a time on the testing desk at reaching distance, and then read aloud the instructions (e.g. "Please lift this tray"). No indication about using one or two hands was given. Instructions could be repeated before starting the task if requested or if the participant did not initiate the task within 1 min. There was no time constraint to perform the task. Participants were asked to perform each task three times ("attempts") consecutively. After each attempt, the examiner placed the objects on the testing desk again, the participants' arms were placed on their lap, and the participants were asked to perform the same task a second and then a third time (e.g. "Please lift this tray again"). Once they had completed (successfully or not) the three trials, the object (or set of objects) was removed from view and a new task with a different object/s was proposed. The 8 different tasks were presented in a fixed randomised order. For each attempt, the participants received an error score from 0 to 3, where 0 indicated that the participant promptly carried out with one hand the task using the "aware strategy"; 1 indicated that the participant carried out the task using one hand but with some hesitation; 2 indicated that the participant started the task as if they could use two hands but then they corrected themselves using the "aware strategy"; 3 indicated that the participant behaved as if s/he could use two hands and this resulted in a "failure due to anosognosia" (see Table 2). Error scores ranged from 0 to 24 for each of the three (first, second and third) attempts. Failures due to lack of comprehension, apraxia or agnosia would have led to behaviour qualitatively different from those identified in Table 2 (see "failure for anosognosia") and therefore were not considered in the analyses.

No feedback (verbal or otherwise) was provided by the examiner, however some feedback was intrinsic in cases of total or partial failures (see "evidence of failure" in Table 2).

Healthy volunteers were explicitly asked to perform the task using one hand only. To investigate any possible effect of the hand used, 9 of them performed the tasks using their right and 10 using their left hand.

Brain damaged and control patients were first assessed with the VATAm and then with the BMT.

3. Results

3.1. Explicit anosognosia

3.1.1. The VATAm upper limb

All 30 brain-damaged patients completed the VATAm and provided the expected rating to all the check questions. Thirteen (43%) showed evidence of anosognosia for their motor impairment. Of them, 3 (10%) showed mild, 7 (23%) moderate and 3 (10%) severe anosognosia. Of these 13 patients, 8 (61.5%) had lesions encompassing the frontal or the parietal lobe. None of the control patients showed evidence of anosognosia.

3.2. Implicit anosognosia

3.2.1. The bimanual task

The first attempt with the BMT represents the patients' knowledge about their own motor impairments, with no previous direct experience of failure or partial failure at that specific task. The following two attempts indicate the patients' awareness following a recent direct experience of failure or difficulty in performing the required task. Therefore, performance during first attempt was considered separately for second and third attempts.

3.2.2. BMT – first attempt

The control groups' average error score was 2.31/24 (sd = 2.46; range 0–9). Healthy volunteers obtained an average error score of 2.84/24 (sd = 2.56; range = 0–9), and no effect of the hand used was found ($F(1,18) = 1.85$; n.s.). Control patients obtained an average error score of 0.86/24 (sd = 1.46; range = 0–4). Brain damaged patients obtained an average error score of 5.27/24 (sd = 6.16; range = 0–19). Performance of the three groups differed significantly ($F(2, 55) = 3.06$; $p < .05$). Differences in performance amongst the three groups were further investigated by means of Dunnett post hoc analysis, which showed a significant difference between brain damaged patients and control patients ($p < .005$). The trend of a poorer performance of the healthy volunteers compared to the control patients might be due to the fact that the healthy controls were relatively new to this condition, while the control patients have been exposed to similar situations before, hence they could benefit from previous experience. However, the performance between the two control groups did not differ significantly suggesting no obvious effect of education in performing the BMT.

In order to interpret each individual brain damaged patient's performance as normal or pathological, we identified a cut-off value, which indicated the threshold between normal and pathological performance. According to Crawford's modified *t*-test (Crawford & Garthwaite, 2007), an error score of 9 is significantly (with $p < .01$) different from the control groups' performance. Note that none of the control participants performed above this cut-off. Hence an error score equal to or over 9 was considered as evidence of implicit anosognosia.

Seven (23%) brain damaged patients showed evidence of implicit anosognosia, and their average error score was15.29 (sd = 2.93; range = 10–19). Five of these 7 patients (71.4%) had brain lesions encompassing the fronto-parietal areas.

3.3. Explicit and implicit anosognosia dissociations

3.3.1. VATAm and BMT

We next compared the performance of the 30 brain damaged patients on the VATAm upper limb and the first attempt of the BMT. Five (17%) patients showed anosognosia on both tests, while 15 (50%) did not show signs of unawareness on either test. However, 2 (7%) patients (cases no. 1 and 3) showed anosognosia on the BMT only, whereas 8 (27%) patients (cases no. 5, 6, 12, 15, 20, 22, 23, 24) showed anosognosia on the VATAm only.

To overcome the possible criticism of a weak double dissociation mainly resulting from the patients' scores close to cut-offs, we considered also very overt cases of anosognosia, i.e. VATAm upper limb scores over 8.1, which is the cut-off for moderate anosognosia (Della Sala et al., 2009), and BMT error scores over 12.22, which is the error score at 4 standard deviations from our control groups' mean. Similarly, we considered only cases of obviously normal performance, i.e. VATAm upper limb scores lower than 2.56, which is the score within 1 standard deviation from the normative group reported in Della Sala et al. (2009), and BMT error scores lower than 5.13, which is the value within 1 standard deviation from our control groups' mean. According to this stricter criterion, 7 cases of double dissociations could still be singled out: 2 patients showed severe anosognosia solely on the BMT, while 5 patients showed severe anosognosia on the VATAm only.

3.4. The effect of empirical learning

3.4.1. BMT – second and third attempts

Both control groups generally performed close to ceiling on the first attempt, however they improved even further on the second and third attempts. Control patients obtained an identical performance on second and third attempts with an average error score of .57/24 (sd = 1.51; range = 0–4); whereas healthy volunteers obtained an average error score of .42/24 (sd = .96; range = 0–4) and of .32 (sd = .75; range = 0–4) on second and third attempts, respectively. The difference between the two attempts was not significant ($F < 1$).

None of the 23 brain damaged patients performing within the normal range during the first attempt showed anosognosia on second and third attempts. The group performance on the second (error score = 4.20/24; sd = 5.31; range = 0–17) and the third (error score = 2.37/24; sd = 4.55; range = 0–17) attempts was better than on the first attempt (see Section 3.2.2: average error score = 5.27/24; sd = 6.16; range = 0–19). Error scores of the three test attempts were entered in a repeated measures ANOVA that showed a significant improvement across the three attempts ($F(2,58) = 11.24$; $p < .001$). Post hoc paired t-tests showed that each attempt significantly differed from the previous one (first–second attempts with $p < .05$; second–third attempts with $p < .005$; first–third attempts with $p < .001$).

To better investigate the impact of empirical learning, we considered individual performance over the three attempts of the 7 brain damaged patients who showed implicit anosognosia during the first attempt. Despite all of them showing at least some improvement across the three attempts, only 5 (cases no. 1, 3, 7, 10, 18) scored within the normal range on the second or the third attempts. Interestingly, only 3 of them (cases no. 1, 7 and 10) performed within the normal range on a follow-up assessment 3 days later, suggesting that some patients regained awareness only temporarily. Both group and individual analyses showed that most of the brain damaged patients tend to improve their performance (modifying their behaviour accordingly to the motor deficit), and then increase their awareness, following the simple exposure to a total or partial failure while they attempt the task.

4. Discussion

Nearly half of the brain damaged patient group showed some degree of explicit anosognosia, whereas only a quarter of them showed implicit anosognosia. This means that some patients explicitly denied a deficit despite having some insight into it, as they correctly approached bimanual tasks according to their motor impairment. Looking at the individual data, 8 patients showed selective explicit anosognosia and for 5 of them the lack of awareness was severe or moderate. These findings would be hard to explain by simply maintaining that the VATAm is more sensitive to lack of awareness than the BMT as the opposite dissociation (i.e. selective implicit anosognosia) was also observed in 2 patients. The double dissociation rather suggests that different mechanisms may be responsible for explicit and implicit unawareness. Our lesion data were uninformative on this matter, as we could not identify a clearly different behavioural pattern between patients with anterior cortical lesions and those with subcortical lesions. However, recent EEG/ERP studies (Vocat et al., 2008 and Vocat and Vuilleumier, 2010) have suggested that different patterns of activation may reflect two different neural pathways associated with distinct implicit and explicit levels of awareness.

The performance of patients showing selective explicit anosognosia cannot be accounted for by a general failure in performing an appropriate self-evaluation (Levine, 1990) or by an incorrect monitoring of reality (e.g. Goldberg & Barr, 1991) as they modified their behaviour on the BMT to account for their motor deficit, showing some insight into the deficit. Moreover, we also doubt that this dissociation can be explained as the result of a too poor or incomplete elaboration of feedback, which did not reach a conscious level. In fact, the behaviour of these patients on the BMT was appropriate to their motor impairment, implying that information about motor abilities was processed well enough to induce a behavioural modification. However, this information is not necessarily generalised to an explicit acknowledgment of the deficit. Alternatively, these patients might show psychological denial of their motor impairment (Turnbull and Solms, 2007a, Turnbull and Solms, 2007b and Weinstein, 1991). Within this frame of reference, some insight of the deficit is fundamental in order to trigger the denial as a mechanism of defence. Therefore, it is possible that these patients may have denied their impairment when it was enquired about directly, but in less obvious (and probably less "threatening") situations the defence mechanism may be weakened and the patients' behaviour automatically "adjusted" in accordance with their actual motor disabilities. The dissociating behaviour of these patients is reminiscent of those patients, reported in the literature, who acknowledge "their" general diseases (e.g. Conson, Ranieri, de Falco, Grossi, & de Falco, 2008) or specific motor (e.g. Marcel et al., 2004) or language (e.g. Kinsbourne & Warrington, 1963) impairment only when they attributed it to someone else.

The opposite dissociation was also observed, that is some patients showed implicit, but not explicit, anosognosia. The number of patients showing this type of dissociation is quite small (only 2 patients) but the phenomenon is robust as it persisted also when a very conservative criterion of dissociation was used. The behaviour of these patients resonates those of patients often described by clinicians and also reported in the literature (e.g. Anton, 1898, Bisiach and Geminiani, 1991 and Marcel et al., 2004) who acknowledge their motor impairment but then attempt actions which are risky or impossible for paretic people or insist to be dismissed from the hospital to go back to their usual activities which require motor skills that they no longer have. An anecdote related to one of our patients (case no. 1) showing selective implicit anosognosia is of some interest. This patient acknowledged his severe left hemiplegia during the neuropsychological assessment with the VATAm, however on one occasion, while waiting in his wheelchair for the lift, he said "The lift is taking ages…why don't we take the stairs?". This case can be hardly interpreted as a patient's fluctuation of awareness, as he consistently reported his motor impairment if enquired, and lack of awareness was mainly observed in less explicit situations. In line with his BMT results, this anecdote rather suggests a lack of insight about the severe motor impairment.

Cocchini et al. (2009) suggested that some patients, especially after some time had elapsed since their brain damage, may have "learned" how to respond to more explicit questions about the deficit, even if they still lack a subjective insight into the deficit. Della Sala et al. (2009) observed that the questions in the VATAm more similar to those contained in structured interview or general conversation (e.g. clapping hands, walking) were also those associated with the poorest prediction of unawareness, suggesting that some patients may be inclined to provide a "learned response" rather than base their replies on what they actually believe or experience. Interestingly, the 2 patients of the current study who showed a selective severe implicit anosognosia were both in chronic/sub-acute phases (i.e. onset from the brain damage 80 and 30 days, respectively) suggesting that they could have been exposed to several direct questions or comments about their motor impairment and they may have "learnt" how to reply in these circumstances.

Taking these findings together, it seems clear that no unitary explanation can account for the different behaviours shown by anosognosic patients. We suggest that different causes, both cognitive and motivational, may prevent patients from becoming fully aware of their motor impairment. These will lead to different forms of anosognosia that could be identified by looking at the different patterns of manifestations.

A second relevant finding of this study consists of the impact of empirical learning on patients' awareness and its effect on performance. Sometimes anosognosic patients firmly deny their motor impairment despite experiencing clear failure in carrying out a motor task (e.g. Ramachandran & Blakeslee, 1998), whereas others may acknowledge temporarily their deficit if this is demonstrated to them (e.g. Cocchini et al., 2002). Our data on the second and third attempts of the BMT provide insight on the effect of experiencing a partial or total failure ("empirical learning") on the patients' behaviour.

Brain damaged patients performed significantly better on the second and third attempts compared to the first one. Moreover, 5 of the 7 patients showing implicit anosognosia during the first attempt managed to modify their behaviour well enough to perform within normal range on second or third attempts. This finding suggests that direct exposure to information indicating a motor failure may be sufficient to lead to a modification of the patients' behaviour accordingly. This implies some increment of their awareness of their motor deficit, and that some patients may behave as anosognosic because of a lack of appropriate feedback. However, insight of awareness can be transient as observed in 2 of these patients who again performed pathologically on the BMT 3 days later. This finding suggests that other factors, such as memory, could affect the maintenance of awareness (e.g. Cocchini et al., 2002 and Davies et al., 2005). From another point of view, some patients' behaviour did not change following clear failure of the BMT. Two patients (cases no. 13 and 21), who also showed severe and moderate forms of explicit anosognosia, performed similarly across the three attempts, continuing with the same type of anosognosic behaviour. This could be explained as a general difficulty in processing and correctly interpreting a failure. Interestingly, 1 of these patients (case 21) showed associated reasoning abilities impairment during the background psychometric assessment (see Table 1). In turn this may be linked to the inability to perform correct self-evaluation that is necessary, according to Levine (1990), to "discover" a deficit and become aware of it.

To conclude, our data are in line with the accruing consensus that deficits of different mechanisms may cause unawareness for illness (e.g. Prigatano, 2010). Anosognosia is a complex cognitive process and malfunctions at any stage can cause lack of awareness. Different patterns of associated deficits may be observed and may represent possible causes (McGlynn & Schacter, 1989). Different methods of assessment may help to tap into different aspects of awareness, and they will contribute to better defining this multi-factorial syndrome and its various possible causes.

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Tables and Figures

Table 1. Demographical, clinical and psychometric data of brain damaged patients and the control groups.

Brain damaged patients	Control patients	Healthy controls	
Number of participants	30	7	19
Gender	11 F; 19 M	4 F; 3 M	10 F; 9 M
Age	65.73 (14.68; 29–87)	66.00 (14.06; 48–88)	60.53 (13.02; 32–79)
Years of education	8.73 (3.50; 5–18)	14.14 (3.08; 12–19)	7.69 (3.80; 5–17)
Interval from brain damage (days)	56.13 (34.58; 13–149)	–	–
Localisation of brain lesion	F = 2; P = 3; F-P = 12; other = 13	–	–
Motor impairment of upper limb (1–100)	29.75 (24.21; 1–61)	76.57 (10.78; 56–85)	–

Where appropriate, standard deviation and range are given in brackets. F, P and P-F refer to frontal, parietal and fronto-parietal lobes lesions, respectively. Other refers to subcortical and posterior cortical lesions.

Table 2. List of tasks and scoring according to motor difficulties and awareness.

Task	Two-hand tasks	One-hand task		Evidence of failure
	No motor disorders	Awareness strategy	Failure due to anosognosia	
1. To hold a two-handle tray	Placing one hand at each extremity	Placing one hand below and in the middle of the tray and lifting the tray	Placing the unimpaired hand at one extremity	The tray falls or is inclinated on one side.
2. To wear a glove on the unaffected hand	One hand holds the glove while the other is slipped in	Placing the glove on the table and inserting the unimpaired hand while either applying mild pressure to avoid the glove moving away or lifting the hand and putting the glove on using the teeth	Picking up the glove with the unimpaired hand and waiting for appropriate movement of the other hand	The glove remains on the table and cannot be worn.
3. To place toothpaste on a toothbrush	One hand holds the toothbrush while the other applies the toothpaste	Using the unaffected hand, placing the toothbrush on the table and then applying the toothpaste	Holding the toothbrush (or the toothpaste) and waiting for appropriate movement of the other hand	The toothpaste (or toothbrush) remains on the table and no toothpaste is applied.
4. To crack a hazelnut	Holding the nutcracker with one hand and the hazelnut with the other	Using the unaffected hand, placing the nutcracker wide open on the table, then placing the hazelnut in the nutcracker and crushing it[a]	Holding the nutcracker (or the hazelnut) and waiting for appropriate movement of the other hand	The hazelnut or the nutcracker remains on the table and the hazelnut cannot be cracked

5. To open a bottle	**Keeping the bottle steady with one hand and removing the cork with the other**	**Using the unaffected hand, first placing the bottle between the legs and then attempt to remove the cork with the corkscrew**	**Holding the bottle (or the corkscrew) and waiting for appropriate movement of the other hand**	**The bottle or the corkscrew remains on the table and the corkscrew is not in contact with the cork.**
6. Open an umbrella	**Placing one hand on the frame or the handle and opening the umbrella with the other one**	**Using the unaffected hand, putting the umbrella frame/handle between the legs and then attempt to open the umbrella[a]**	**Putting the unaffected hand on the frame/handle and waiting for appropriate movement of the other hand**	**The umbrella remains on the table folded.**
7. To clap hands	**Clapping both hands**	**Leaving (placing) the affected hand open on the clap or on the table and clapping with the other**	**Moving the unaffected hand only as if it were clapping**	**No clapping sound.**
8. To open a heavy book[b]	**Holding the book with one hand and opening it at a specific page with the other hand**	**Using the unaffected hand, placing the book on the table and opening it at a specific page**	**Holding the book and waiting for appropriate movement of the affected hand**	**The book remains closed.**

[a] Action was not expected to be completed (e.g. attempt to partially open the umbrella using the awareness strategy was considered a satisfactory response).

[b] The book was handed to the patient (not placed on the table).

Fig. 1. [no image] Types of performance on the bimanual task "To hold a two-handle tray". (a) No motor disorder – using both hands; (b) using one hand by holding the two-handle tray by placing one hand underneath the centre of the tray – "awareness strategy"; (c) using one hand by placing the unimpaired hand at one extremity – "anosognosia".